

THE EFFECTS OF LISTENING TO MUSIC ON
COGNITIVE TASK PERFORMANCE

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Leslie Anne Angel

The Department of Psychology

UNIVERSITY OF DAYTON

Dayton, Ohio

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APPROVED BY:

Donald J. Polzella, Ph.D.
Chairperson, Thesis Committee

Greg C Elvers, Ph.D.
Thesis Committee Member

Charles E. Kimble, Ph.D.
Thesis Committee Member

CONCURRENCE:

David W. Biers, Ph.D.
Chairperson, Department of Psychology

ABSTRACT

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Name: Angel, Leslie Anne
University of Dayton, 2003

Advisor: Dr. D. J. Polzella

Research on the effects of listening to background music on cognitive task performance has had a long history with varied results (e.g., Hall, J. C., 1952; Jensen, M. B., 1931; Mikol, B. & Denny, M. R., 1955). The present study investigates the influence of one type of previously selected music on cognitive task performance within the context of the multiple resources theory (Wickens, C. D., 1984, 1991) and arousal research (Boff, K. R. & Lincoln, J. E., 1988). Two standardized test batteries from the Criterion Task Set (CTS), developed at the United States Air Force's Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL), were selected to assess verbal and nonverbal performance. A linguistic processing task was chosen as the linguistic task, while a spatial processing task was chosen to represent the nonlinguistic task. Ten excerpts from Wolfgang Amadeus Mozart's (1756-1791) music, performed by Richard Fuller on hammerflugel and fortepiano, were selected and matched

for tempo (fast). Based on the results of a pilot study, performance was expected to become worse for participants who performed the linguistic task while listening to music. Listening to music was not expected to interfere with the performance of a spatial task.

During the present study, reaction time was significantly lower during the music condition for the spatial task. These results partially support the hypothesis that listening to music would not interfere with the performance of a nonlinguistic task due to a lack of competition among separately processed resources (Wickens, C. D. 1984; 1991). The multiple resources theory does not account for the increased performance during this task. Also, accuracy was found to significantly increase when participants listened to music during the linguistic task. This finding stands in contrast to the hypothesis that listening to music interferes with linguistic task performance. Increased linguistic and spatial task performance during the music condition may have resulted from the maintenance of an intermediate level of arousal necessary for optimal performance (Boff, K. R. & Lincoln, J. E., 1988).

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CHAPTER I

INTRODUCTION

Historical Perspectives

Those involved in monotonous or repetitive work environments, including both factory workers and college students, typically desire background music when working, and choose to listen to music when given the option of music or silence (e.g., Kerr, 1943a, 1943b; Middleton, Fay, Kerr, & Amft, 1944; Smith, 1947). While the subjective appeal of music has been consistently documented in the literature for more than half a century, the effect of background music on the performance of daily tasks is less clear. Further, early reports from commercial research teams about the supposed benefits of background music may have embellished the effectiveness of background music on employee competence; from enhanced ability, increased productivity, and stress-reduction, to a limitation in the number of trips employees make to the restroom, a cutback in tardiness, and a minimization in the number of employee turnovers (Pooock & Wiener, 1966). Such commercial claims regarding the effectiveness of music on performance rates were rarely matched by scientific evidence.

The bias of early commercial claims on music's production-enhancing qualities created a need for the scientific study of the effects of music

performance. Many previous studies focused on the effect of different types of music on performance (e.g., Cockerton, Moore, & Norman, 1997; Rauscher, Shaw, & Ky, 1993; Smith & Morris, 1977; Stough, Kerin, Bates, and Mangan, 1994). Other studies typically looked at the effect of the listener's familiarity with the selected music, the influence of rhythm and tempo, the loudness of the music, or the consequences of task variation or task difficulty while listening to music on performance (e.g., Fontaine & Schwalm, 1979; Freeburne & Fleischer, 1952; Freeman & Neidt, 1959; Hahn & Hwang, 1999; Hilliard & Tolin, 1979; Mayfield & Moss, 1989; Mikol & Denny, 1955; Smith & Morris, 1977; Wolfe, 1983).

Disappointingly, results from these studies are inconsistent. Scientific research on the effects of background music on cognitive task performance has had a long history with varied results. In one of the earliest studies, Jensen (1931) found that background music decreased the performance of typists. However, Hall (1952) found that student scores on a reading test improved with background music. Mikol and Denny (1955) found no significant difference in pursuit rotor performance between music versus a control condition that utilized a metronome. Curiously, 28 of the 32 participants in Mikol and Denny's study believed that music helped their performance. Based on this finding, it could be argued that the benefits of background music are a sort of placebo effect, in which listeners believe music to help their performance when in actuality their

performance remains consistent or even declines in the presence of music (e.g., Mikol & Denny; Smith, 1961).

More recent research suggests that background music may do more than influence the perceived performance of the listener. Background music may have inherent qualities that improve performance, although the effectiveness of background music may be complex in that it is affected by the interaction of multiple variables. It has previously been suggested that the variation in research results may be contingent upon factors including the music type, the participant's arousal level, the novelty or participant's familiarity with the music selection, the participant's study habits, such as whether or not he or she typically listens to background music, and the task type (e.g., Rauscher et al., 1993). A review of the literature in these categories reveals the complexity of the effect of music on performance.

Freeburne and Fleischer (1952) conducted a study on the effects of four different types of music, including classical, popular, semi-classical, and jazz, to determine the effects of music on reading rate and comprehension. The results revealed that the jazz group read significantly faster than the other music and controlled silence conditions. However, the reading comprehension scores were not significantly different for any of the music or silence conditions. These results indicate that music type may influence speed, but music type does not significantly influence cognitive performance.

In contrast, Smith and Morris (1977) conducted a study in which one of five different types of music, including classical, country/bluegrass, jazz and blues, easy listening, and rock/rock and roll, were played during a cognitive task involving variations of a digit span test to measure recall. Both psychology and music majors heard selections from music categories including stimulating, sedative, and no music while performing the cognitive task. It was found that compared to sedative music, stimulating music was associated with a rise in worry, loss of concentration, and lower performance than expected (Smith & Morris). This finding indicates that stimulating music may have a greater debilitating effect on performance than sedative music.

Cockerton et al. (1997) compared background music with silence and found that music significantly facilitated cognitive performance for thirty undergraduates on a thirty-item, general intelligence measurement. The researchers acknowledge that their results may have been contingent on the type of music selected. Music was utilized from the Koan Plus software package. Koan-created music is derived from Japanese Buddhist philosophy and is described as being “ever changing and free-flowing harmonious music” (Cockerton et al., 1997).

The researchers hypothesized that the natural music may have relaxed participants, who benefited in cognitive task performance because of stress-reduction induced from the music. However, according to the findings of Nantais

and Schellenberg (1999), preference for the music over the silence condition may be a more likely explanation for the increased performance during the music condition. Such determinations cannot be made based on the control and music type selected for the Cockerton et al. (1997) study.

Further explanations for the influence of background music on task performance reside in the arousal level produced by the music (Rauscher et al., 1993). A practical example can be found in Beh and Hirst (1999), who conducted a study that monitored driving-related tasks during high-intensity music, low-intensity music, and silence. Response time decreased during central signals with both high and low-intensity music conditions for tasks of varying difficulty levels. Beh and Hirst also found that high-intensity music was correlated with longer reaction times to peripheral signals during demanding tasks. Moderate-intensity music is suggested as benefiting vigilance (Beh & Hirst).

Also, arousal may be associated with the novelty of the background music, which is suggested as influencing task performance. Interestingly, Fontaine and Schwalm (1979) found that familiar music was associated with increased arousal and heart rate, as well as increased performance on a signal detection task when compared to unfamiliar music. There was no significant effect on performance due to the type of music to which participants were exposed. Further, Hilliard and Tolin (1979) discovered that familiar music was

associated with enhanced performance on a reading comprehension task, even if subjects had only been exposed to the music moments before performing the task. This research stands in contrast to a study by Freeman and Neidt (1959) who observed no significant differences in participants' abilities to learn the content of a film with familiar background music compared to films with unfamiliar background music.

The participant's typical study habits may also influence his or her performance while listening to music. Those who typically listen to music while studying or performing similar cognitive tasks may perform better on a task while exposed to background music than those who typically perform cognitive tasks in silence. Etaugh and Ptasnik (1982) found that college students who rarely listen to music displayed increased reading comprehension during a silent study condition. No difference in performance with background music was found for those who typically study with music (Etaugh & Ptasnik).

Another explanation for the significant performance increases when participants are exposed to background music could be the task type. For example, Flaum (1981) looked at the influence of music on the performance of a verbal and nonverbal visuospatial task. Interestingly, an unfamiliar music with words condition was found to have significantly better results than the noise or silence conditions on the visuospatial task. Flaum suggests that the benefits of music on performance may be limited to non-verbal tasks. Increased

performance on nonverbal tasks while listening to music may occur due to the separate nature of the tasks, while listening to music during a verbal task may serve as a distraction due to the similarity of the lyrics and verbal task content.

The Mozart Effect

Recently, research suggesting an increase in task performance due to listening to Wolfgang Amadeus Mozart's music reached public interest after publications appeared in popular journals, such as *Nature*. Rauscher et al. (1993, 1995) conducted research on the influence of listening to classical music (Mozart), a relaxation tape, or silence on adult spatial IQ. The researchers found that only the classical music condition increased spatial task performance for adults. The significant improvements found in participants' spatial IQs after listening to Mozart, led the result to become known as the "Mozart effect."

Unfortunately, additional follow-up studies of the so-called Mozart effect would lead to its demise. First, a similar study by Stough et al. (1994) measuring the effects of Mozart, popular music, and a silence condition on the spatial processing of children, found no significant differences in the spatial task performance of children for the three conditions. Also, Steele, Bass, & Crook (1999) were unable to replicate the findings of Rauscher et al. (1993, 1995). More recently, Nantais and Schellenberg (1999) found that increased performance attributed to listening to Mozart was eliminated when the silence

condition was replaced by a narrated story. Task performance was determined to be a function of participant preference rather than some enhancing quality of the classical music itself.

Interference

Perhaps a more complex explanation is in order, such as an interaction between task type, music type, and novelty of the music selection to the listener. It is important to determine the effect of independent influences before a more complex hypothesis can be clearly formulated. Two considerations for future study in music and cognition are discussed. First, previously, tasks have rarely been standardized and differ greatly among studies. Standardized testing procedures are required to accurately measure and make predictions about participant performance.

Secondly, a helpful approach to understanding the influence of music on task performance might be to view it from the perspective of the literature on attention. Wickens (1984) has applied a “multiple resource theory” to explain attention and processing during dual-task performance. The multiple resources theory postulates that there is more than one resource or property involved in the processing of information. When applied to task performance, multiple resources theory suggests that tasks will compete for resources if the tasks demand the same type of resources.

Wickens' (1984; 1991) emphasizes that the relationship between two of the tasks affects overall performance. For example, tasks that are similar to one another may result in competition and confusion during processing. To illustrate this, Wickens (1984) uses the example of an individual engaged in a similar conversation with two different people at the same time to illustrate this point. The content of the two conversations will become confused as the individual attempts to make sense out of each discussion. In another example, Wickens notes that simultaneously listening to music and attempting to understand a conversation will interfere with one another because they both utilize auditory processing resources.

Wickens (1984) also suggests that spatial and verbal processing utilize separate processing resources. According to Wickens, dual-task performance using separate or cross-modal processing (e.g., auditory and visual) may result in decreased reaction time compared with tasks involving similar resources (e.g., visual and visual). Attention may be more easily divided between separately processed tasks than similarly processed tasks (Wickens).

The Pilot Study

A pilot study tested the effects of listening to background music as a function of cognitive task performance during a linguistic and a nonlinguistic task. Fifty students (24 males, 26 females) enrolled in Introductory Psychology at the

University of Dayton, served as participants. Because of its regimen of standardized tests to measure performance, two tasks were selected from the Criterion Task Set (CTS) (Shingledecker, 1984). An Unstable Tracking Task based on Jex, McDonnell, and Phatak's (1966) critically unstable tracking task, was selected as the manual task. Also, a Memory Search Task, designed after Sternberg's (1969) memory search paradigm, was chosen for its reliability as a cognitive measurement task.

Both listeners and nonlisteners of background music performed either the manual (nonverbal) or the cognitive (verbal) task. Music and no music conditions were varied within-subjects during both tasks. Participants during both tasks were told that the purpose of the study was to determine if listening to music has an effect on the participant's performance on a manual or cognitive task. Participants selected their own music. The majority of participants (approximately 88%) chose popular contemporary music. The order of the manual and cognitive tasks and the music versus no music condition were systematically varied between participants. The pilot study was conducted over a three-day period—a practice day followed by a second day of more practice and initial testing, and a third day of only testing.

During the Unstable Tracking Task, a cursor centered in the middle of the screen would drift from its position during a block of trials. Participants were to turn a control knob clockwise (up) or counterclockwise (down) with the dominant

hand to keep a cursor centered over a target area located in the middle of the monitor. During half of the trials participants (14 typically listeners and 12 typically nonlisteners of background music) were instructed to listen to music through headphones, while they were asked to turn off the music during the other trials.

Two levels, medium and low, were manipulated as a within-subjects variable during the Unstable Tracking Task. The high level block of trials was eliminated due to its complex nature and inability to produce consistently meaningful results (Schlegel & Gilliland, 1987). Twelve test trials, lasting three minutes each, were preceded by twelve practice trials (six for the low condition and six for the medium condition) over two sessions to eliminate training effects and to produce more stable performance (Shingledecker, 1984). Mean absolute tracking errors were measured by the number of times the cursor was outside of the target area for more than ten seconds at each control loss. Also, the average number of edge violations, or the number of times the cursor entirely evaded the screen, was measured for this task.

During the Memory Search Task participants were asked to memorize a letter or a small set of letters displayed on a monitor. This task is a subject-driven task in which participants were given a maximum of fifteen seconds to memorize the set during the practice trial block. Reaction times were limited during the test trial blocks. After memorization was complete, participants were

to indicate whether or not a series of letters flashed on the screen contained the memorized letter(s) by pushing the left (yes) or right (no) side of a button pad with the dominant hand.

Two levels, low and high, were manipulated as a within-subjects variable for the Memory Search Task. Task levels varied by the memorized set size, as well as the exposure time. The low-level task contained one letter in the memorized set, while the high-level contained six letters in the memorized set. Reaction time was limited to 1.5 seconds for the low-level task and 2.5 seconds for the high-level.

Music versus no music conditions were varied within-subjects (12 typically listeners and 12 typically nonlisteners of background music) for each trial block. Participants were asked to respond “as quickly as possible without making any errors.” Twelve test trial blocks were preceded by fourteen practice trials over two sessions (seven for the low condition and seven for the high condition). The percentage of correct answers and the average reaction time were measured during this study.

Unstable Tracking Task

A mixed-design analysis of variance (ANOVA) was performed for the mean absolute error and the average number of edge violations to test the effect of music on task performance. Mean absolute error was not significantly affected

by the music condition. However, the number of edge violations was significantly reduced during the music condition. The number of edge violations was lower during the more difficult level, particularly when listening to music.

Memory Search Task

Similarly, a mixed-design analysis of variance (ANOVA) was performed for the percent of correct responses and the average reaction time. The number of correct answers was not significantly affected by the music condition. However, an interaction between music and difficulty of task was significant, such that the number of correct responses was in fact lower under the more difficult level, particularly during the music condition. There were no effects of music on reaction time.

The Present Study

Similar to the pilot study, the present study tested the effects of listening to background music as a function of cognitive task performance during a linguistic and nonlinguistic task. The data were interpreted within the context of the multiple resources theory (Wickens, 1984; 1991) and arousal research based on the Yerkes-Dodson Law (Boff & Lincoln, 1988). Pre-selected music was used during the study to reduce the effects of music type on performance.

During the current study, two types of cognitive tasks were drawn from a standardized test procedure, one testing linguistic processing and the other testing spatial, or nonlinguistic, processing. The tasks were empirically tested at the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL) to determine differences in task demand, and to specify task training schedules and performance rates (Shingledecker, 1984). High and low difficulty levels were used for both tasks during the current study. Response speed and degree of effort were found to be the most important predictors of mental workload (Polzella & Reid, 1987). For this reason, performance ratings were based on reaction time and the percentage of correct responses (Acton & Crabtree, 1985). Participants performed both cognitive tasks during a silent condition and a background music condition.

Based on the results of the pilot study, it was predicted that listening to music would not interfere with performance of the spatial task. Listening to music and performing a spatial processing task may require different processing resources (auditory and spatial, respectively) and are not expected to be in competition with one another (Wickens, 1984). It was expected that listening to music would interfere with performance during the linguistic task, which was found in the pilot study.

CHAPTER II

METHOD

The Present Study

Participants

The participants were fifty-one students (23 males, 28 females) who were enrolled in Introductory Psychology at the University of Dayton. Approximately 3.92% of the participants were seventeen years of age, 43.14% were eighteen years of age, 35.29% were nineteen years of age, 9.80% were twenty years of age, 3.92% were twenty-one years of age, 1.96% were twenty-two years of age, and 1.96% were thirty-one years of age. Participation in the study partially fulfilled a research requirement for the course (see Appendix A and B).

Participants acted as both “listeners” and as “nonlisteners.”

One important distinction between the pilot study and the present study is that the condition of those who listen to music versus those who do not listen to music was not incorporated in the present study. There were two reasons for this adjustment. First, the vast majority of undergraduates categorize themselves as “preferring to listen to music while completing academic work at least sometimes,” compared with those who never listen to music while completing

academic work. In a sample survey of 356 undergraduate students at the University of Dayton, 84.5% of the surveyed students indicated that they sometimes listen, frequently listen, or always listen to music while completing academic work; this is compared with only 15.5% of the students who indicated that they never listen to music while completing academic work. Therefore, those who at least sometimes listen to music while completing academic work represent a more typical or common subject pool from which to draw. Secondly, task performance of typical listeners versus nonlisteners of music was not found to differ significantly in either the music or no music conditions during the pilot study and was, therefore, not expected to have an influence on the results of the current study.

Apparatus

The apparatus consisted of a 6510-based microcomputer (Commodore) and a 1702 (Commodore) color monitor. Because of its regimen of standardized tests to measure performance, the Criterion Task Set (CTS) (Shingledecker, 1984) was used for this study. The CTS, which was developed at the United States Air Force's Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL), is a standardized test battery for assessing various aspects of human performance. Two of the test modules were used to measure cognitive

performance: The Linguistic Processing Task and the Spatial Processing Task. The CTS's Linguistic Processing Task is based on a letter-matching task developed by Posner and Mitchell (1967), as well as a depth of processing task by Schulman (1974) and Craik and Tulving (1975). The CTS's Spatial Processing Task is modeled after a task by Chiles, Alluisi, and Adams (1968).

In the Linguistic Processing Task, the participant views letter pairs on a monitor. Each letter is approximately 0.5 x 0.7 cm. Letters were viewed on the monitor from a comfortable distance. The participant attempts to classify letter pairs as being either the same or different as an indicated dimension. Two dimensions were used, including a low-level physical letter match, during which letter pairs must be physically identical to match, and a medium-level category match in which letters must be either vowels or consonants to match. The participant indicated either "yes" for a match or "no" for no match on a control pad. According to Shingledecker (1984), the classification type affects the response time and the extent of incidental learning of the stimuli. Participants were given 1.0 seconds to respond for the low-level task and 1.5 seconds to respond for the medium-level task during the test trial blocks. Each participant was given 15.0 seconds to respond during the practice trial blocks.

In the Spatial Processing Task, participants are asked to watch a series of histograms displayed one at a time on a monitor. Histograms vary in both height and degree of angle. Bar heights range from one to six arbitrary units and are

displayed at 0-degree, 90-degree, 180-degree, and 270-degree angles. Two levels are employed: a low-level task in which two bar histograms are compared at 0-degree angles and a high-level task during which six bar histograms are compared at 180-degree angles. The participant must determine if a subsequent (comparison) histogram is the same as or different than a previous (target) histogram in terms of bar heights. The participant indicated either “yes” for a match or “no” for no match on a control pad. Target histograms are displayed for 3.0 seconds. Participants are given 1.5 seconds to respond to the comparison histogram in the low-level condition and 3.5 seconds to respond to the comparison histogram in the high-level condition.

Average reaction times and subjective task difficulty ratings were measured for both tasks. Music type was held constant during the present study to eliminate confounding factors, such as participant preferences and familiarity, as well as differences in musical selections, such as tempo and genre. Excerpts from ten pieces by Wolfgang Amadeus Mozart (1756-1791), performed by Richard Fuller on hammerflugel and fortepiano, were selected and matched for tempo (fast). Musical selections are listed in Appendix C.

Procedure

Participants were told that the purpose of the study was to “determine if listening to background music [would] have any effect on [an individual’s]

performance on a cognitive task.” The experiment employed one between-subject variable, task (linguistic or spatial processing), and three within-subject variables, music-no music, task difficulty levels (two), and trials (three).

Previously selected music was played on headphones during the tasks in the music condition versus silence during the no music condition. Musical selections were randomly numbered from one to ten. Musical excerpts were held constant within participants, such that each participant listened to the same piece during each music trial block. The numbered excerpts were varied between participants using a counterbalancing technique based on condition order (see Appendix D). For example, participants assigned to linguistic order 1 listened to musical selection 2. Participants assigned to linguistic order 2 listened to musical selection 1.

For both tasks, five conditions were generated. The order of the linguistic and spatial tasks was varied between participants, such that the first participant was assigned to the first linguistic task and the second participant was assigned to the first spatial task. The music versus no music test conditions were varied between participants using a counterbalancing procedure. Linguistic order 1 is shown in Appendix D as an example. The experiment was conducted over a three-day period—a practice day, followed by a second day of more practice and initial testing, and a third day of only testing. Based on the recommendation of

Shingledecker (1984), ten practice trial blocks were conducted for each level of the cognitive tasks to maximize performance stability. Twelve three-minute test trial blocks with alternating music and no music conditions were preceded by ten practice trial blocks without music. During half of the Linguistic Processing Task trial blocks participants were instructed to listen to music through headphones, while they were asked to turn off the music during the other trial blocks. Two levels, low and medium, were manipulated as a within-subjects variable.

Two levels during the Spatial Processing Task, low and high, were manipulated as a within-subjects variable. Music versus no music conditions were varied within-subjects participants during each trial block. Participants were asked to respond “as quickly as possible without making any errors” (Shingledecker, 1984). Again, twelve three-minute test trials with alternating music and no music conditions were preceded by ten practice trials at the recommendation of Shingledecker.

Based on the results of the pilot study, reaction time was expected to decrease for participants who performed the spatial task with music. Reaction time was expected to increase for participants performing the linguistic task while listening to music. This result is expected because the available resources are expected to be in competition with one another during similarly processed tasks (Wickens, 1984). Music is thought to serve as a distraction to linguistic performance.

CHAPTER III

RESULTS

For the present study, a mixed within-subjects factorial design was used to test the effect of music on task performance for the Linguistic and Spatial Processing Tasks. Following the suggestion of Winer (1962), the data were normalized as follows: transformed proportion correct = $2 \arcsin \{\text{SQRT}(X)\}$ and transformed reaction time = $\log X$. Boxplots revealed that four of the participants were considered outliers because these participants' scores were more than one and a half box- lengths beyond the box (Kinnear & Gray, 2000). These participants were removed from the analysis.

Spatial Processing Task

A mixed-design analysis of variance (ANOVA) was performed for average reaction time and accuracy for the transformed data. One participant outlier was removed from the spatial processing data set for reaction time. Mean and standard deviation for the transformed reaction times are indicated in Table 1. Analysis on the effect of the music condition for reaction time revealed a

significant main effect, such that reaction time decreased during the music condition, $F(1, 23) = 18.74$, $MSE = 0.02$, $p = 2.48 \times 10^{-4}$. Reaction time was longer during the difficult level, $F(1, 23) = 239.26$, $MSE = 3.2$, $p = 1.119 \times 10^{-13}$. Further, reaction time decreased as the trials increased, $F(2, 46) = 8.95$, $MSE = 0.03$, $p = 0.001$. Neither difficulty level nor trial block interacted with music. The findings are summarized in Figure 1.

Table 1

Mean and Standard Deviation for the Transformed Reaction Time of the Spatial Processing Task

		Difficulty Level						
		Low			High			
Music		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Row Means
Mean		2.781	2.766	2.748	2.997	2.980	2.958	2.872
SD		0.093	0.089	0.102	0.109	0.092	0.112	
No Music								
Mean		2.807	2.779	2.769	3.013	2.993	2.975	2.889
SD		0.099	0.091	0.087	0.102	0.100	0.105	
Column Means		2.794	2.773	2.759	3.005	2.987	2.967	

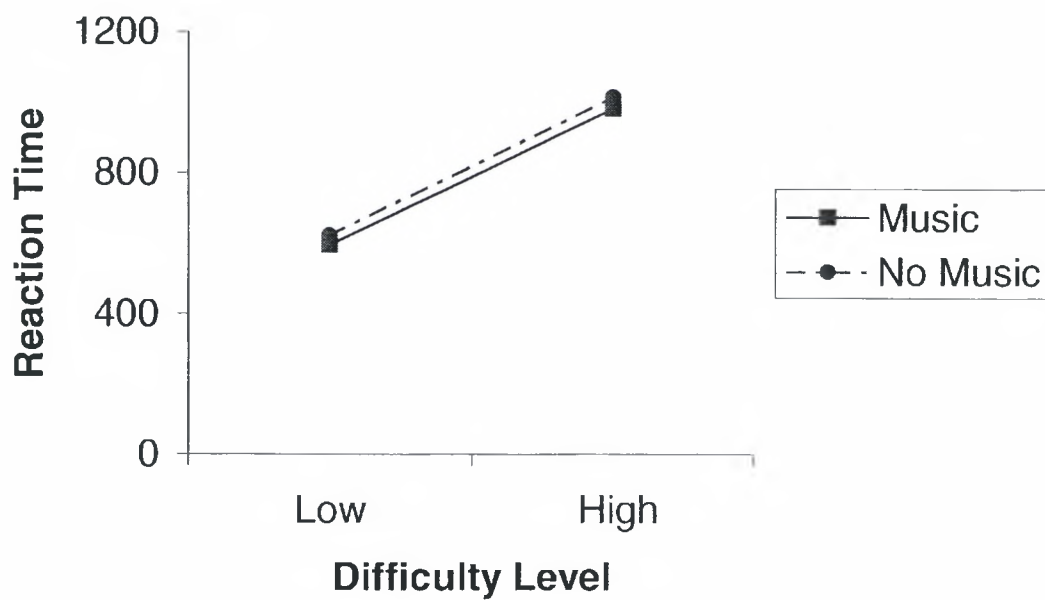


Figure 1. Reaction time for the Spatial Processing Task as a function of music condition and difficulty level.

Similarly, a mixed-design analysis of variance (ANOVA) was performed on the transformed accuracy data. Mean and standard deviation for the transformed accuracy data are indicated in Table 2. Accuracy was not significantly influenced by the music condition, $F(1, 24) = 0.19$, $MSE = 0.03$, $p = 0.667$. Accuracy significantly decreased across the difficulty block interacted with music. The findings are summarized in Figure 2.

Linguistic Processing Task

A mixed-design analysis of variance (ANOVA) was performed for average reaction time and accuracy for the transformed data. Mean and standard deviation for the transformed reaction times are indicated in Table 3. The reaction time was not significantly different during the music condition, $F(1, 25) = 2.86$, $MSE = 0.002$, $p = 0.103$. However, reaction time was significantly longer during the difficult level, $F(1, 25) = 303.51$, $MSE = 1.88$, $p = 1.67 \times 10^{-15}$. Reaction time significantly decreased as trials increased, $F(2, 50) = 26.46$, $MSE = 0.02$, $p = 1.45 \times 10^{-8}$. Neither difficulty level nor trial block interacted with music. The findings are summarized in Figure 3.

Three participant outliers were removed from the Linguistic Processing data set for accuracy. Similarly, a mixed-design analysis of variance (ANOVA) was performed on the transformed accuracy data. Mean and standard deviation for the transformed accuracy data are indicated in Table 4. Accuracy improved

during the music condition, $F(1, 22)=17.37$, $MSE = 0.094$, $p = 4.01 \times 10^{-4}$. Also, accuracy was significantly worse during the difficult level, $F(1, 22) = 36.11$, $MSE = 1.13$, $p = 4.77 \times 10^{-6}$. Neither difficulty level nor trial block interacted with music. The findings are summarized in Figure 4.

Table 2

Mean and Standard Deviation for the Transformed Accuracy Data of the Spatial Processing Task

Music	Difficulty Level						Row Means
	Trial 1	Low Trial 2	Trial 3	Trial 1	High Trial 2	Trial 3	
Mean	2.950	2.876	2.836	2.735	2.606	2.683	2.781
SD	0.277	0.248	0.316	0.343	0.330	0.318	
No Music							
Mean	2.937	2.801	2.896	2.682	2.556	2.702	2.762
SD	0.294	0.350	0.301	0.366	0.362	0.318	
Column Means	2.944	2.839	2.866	2.709	2.581	2.693	

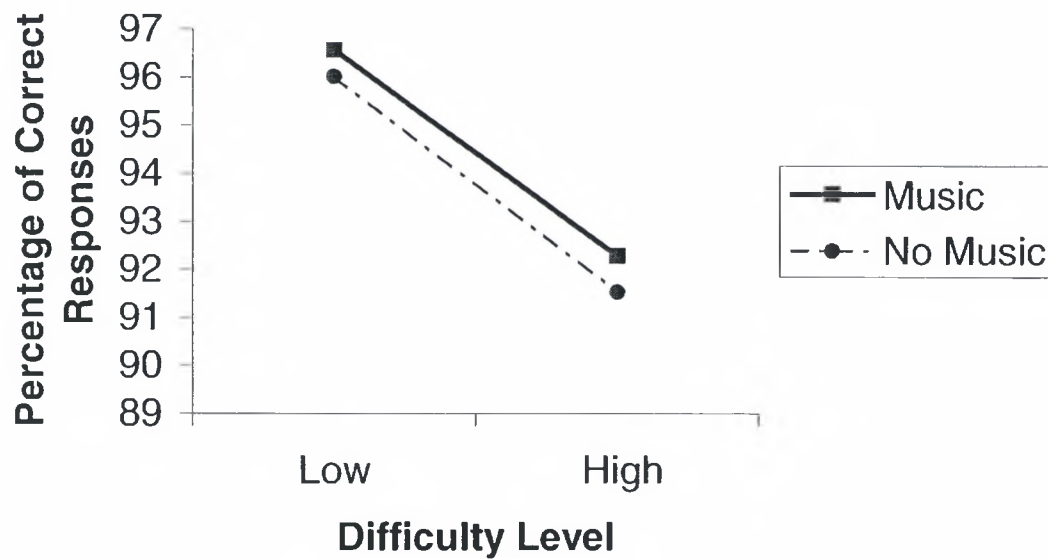


Figure 2. Percentage of correct responses for the Spatial Processing Task as a function of music condition and difficulty level.

Table 3

Mean and Standard Deviation for the Transformed Reaction Time of the Linguistic Processing Task

		Difficulty Level					
		Low			Medium		
Music	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Row Means
Mean	2.673	2.667	2.663	2.840	2.821	2.803	2.745
SD	0.043	0.045	0.039	0.065	0.065	0.069	
No Music							
Mean	2.670	2.659	2.655	2.837	2.817	2.802	2.740
SD	0.050	0.039	0.037	0.064	0.065	0.063	
Column Means	2.672	2.663	2.659	2.839	2.819	2.803	

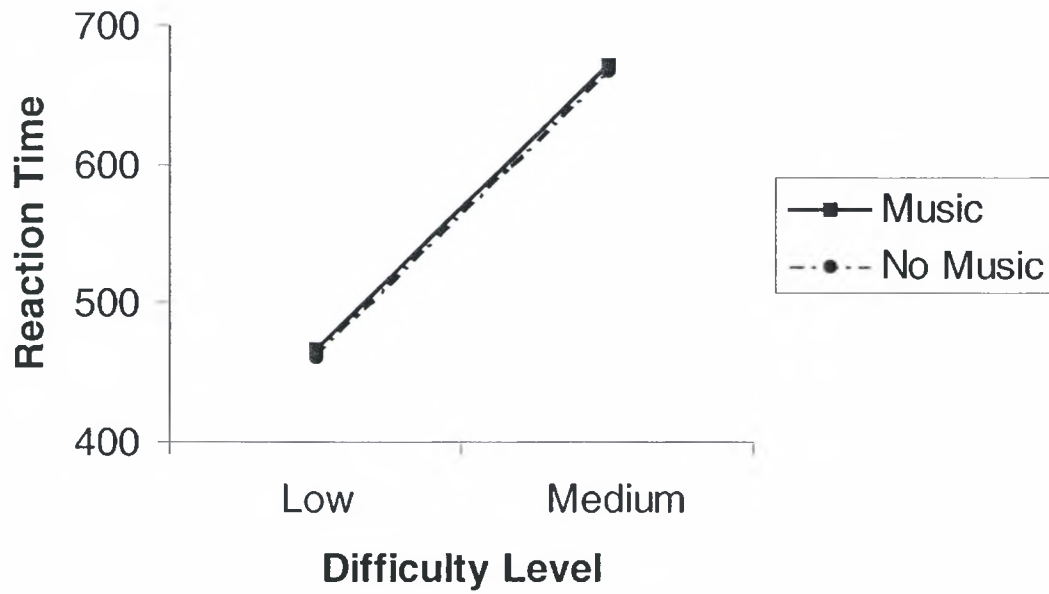


Figure 3. Reaction time for the Linguistic Processing Task as a function of music condition and difficulty level.

Table 4

Mean and Standard Deviation for the Transformed Accuracy Data of the Linguistic Processing Task

Music	Difficulty Level						Row Means
	Low		Trial 3	Medium		Trial 3	
	Trial 1	Trial 2		Trial 1	Trial 2		
Mean	2.873	2.844	2.863	2.726	2.740	2.731	2.796
SD	0.113	0.152	0.171	0.122	0.162	0.171	
No Music							
Mean	2.834	2.826	2.811	2.684	2.689	2.713	2.760
SD	0.130	0.161	0.157	0.113	0.175	0.156	
Column Means	2.854	2.835	2.837	2.705	2.715	2.722	

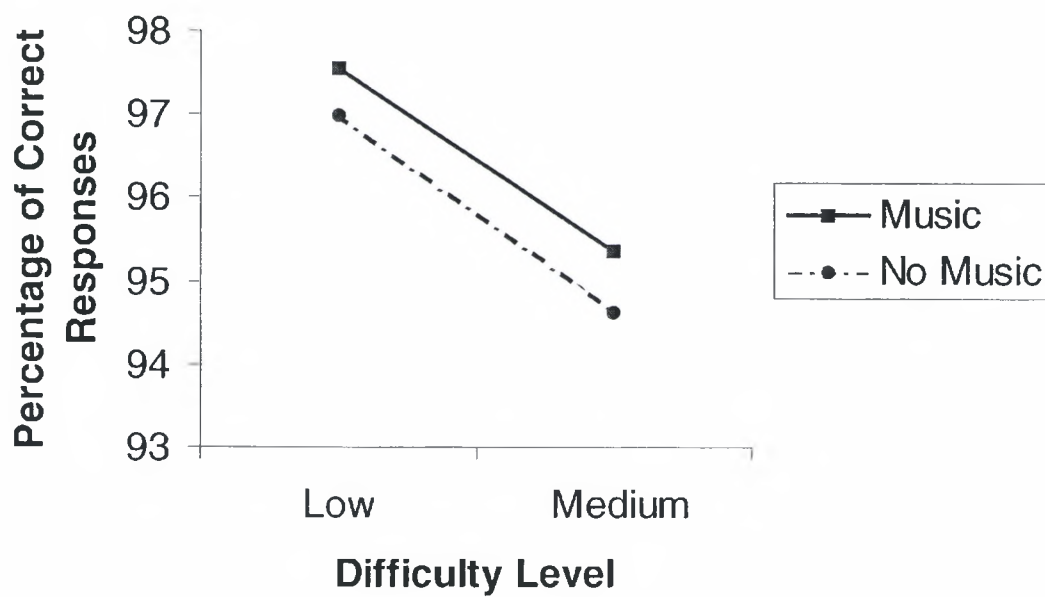


Figure 4. Percentage of correct responses for the Linguistic Processing Task as a function of music condition and difficulty level.

CHAPTER IV

DISCUSSION

The number of edge violations was significantly reduced during the music condition of the Unstable Tracking Task in the pilot study. This effect was particularly contingent upon difficulty level, such that the number of edge violations decreased most significantly during the more difficult level, particularly when listening to music. During the Memory Search Task, the number of correct answers decreased most significantly during the more difficult level, particularly when paired with music.

Observed trends during the pilot study suggested that differences in the Memory Search Task versus those in the Unstable Tracking Task during music could be associated with linguistic and nonlinguistic processing, respectively. According to this theory, performance would increase during the nonlinguistic, Unstable Tracking Task, when performed with music. However, performance would decrease while listening to music during the more linguistic-based, Memory Search Task.

To test the theory generated by the pilot study, two different tasks that utilize linguistic and nonlinguistic resources were selected. For this study, the

Linguistic Processing Task was chosen as the linguistic task, while the Spatial Processing Task was chosen to represent the nonlinguistic task. Further, music was held constant during the present study to reduce confounding factors, such as tempo and genre of the music type selected. Lastly, the present study eliminated the condition of those who typically listen to music versus those who typically do not listen to music during academic tasks. This alteration was made because most individuals listen to music at least sometimes while performing academic tasks and because the listener versus nonlistener of music condition was found to produce no significant results during the pilot study.

Based on the results of the pilot study, performance was expected to improve for participants who listened to music while performing the nonlinguistic task. Wickens' theory is limited in accounting for this improvement and an alternative theory is discussed. Performance was expected to become worse for participants who performed the linguistic task while listening to music. This hypothesis is consistent with the multiple resources theory, which suggests that similar tasks may result in competition for a limited amount of resources (Wickens, 1984; 1991).

During the present study, reaction time decreased while listening to music during the Spatial Processing Task. This result was consistent with the pilot study during which performance increased during the music condition for the nonlinguistic task. The findings of the present study partially support the multiple

resources theory (Wickens, 1984; 1991). The multiple resources theory suggests that when two tasks demanding the same resources are performed simultaneously, one task will interfere with the other task and result in a reduction in performance if the processing demand is greater than the available resources (Wickens, 1984). Because spatial processing involves different processing resources than listening to music, the two tasks were not expected to interfere with one another. However, performance *increased* during the nonlinguistic or Spatial Processing Task. While Wickens theory accounts for a lack of interference, it does not offer an explanation for improved performance while listening to music during a spatial task.

Contrary to the hypothesis that performance would decrease during the linguistic task, accuracy significantly increased during the music condition for the Linguistic Processing Task. Therefore, performance increased during the music condition for the linguistic task, as well as for the nonlinguistic task. Based on the multiple resources theory, it was expected that listening to music would interfere with linguistic processing because of the similarity of the two tasks. The similarity in processing is thought to create competition between available processing, resulting in a decline in performance of at least one of the competing tasks. One reason for the present study's findings may be that nonvocal music was used. Competition between processing resources may only be evident when a linguistic task is paired with vocal musical selections. The familiarity of the music may be

another reason for the differences observed between the pilot and the present study.

Wickens' (1984, 1991) theory of dual-task performance is limited in explaining the results of the present study. It is not clear if the resources utilized during linguistic processing are similar to the resources used while listening to music. Similarly, it is unclear if the resources used during spatial processing are distinctive from those used while listening to music. Wickens' theory is limited in that similar resources are defined as those that produce interference, while separately processed resources are those that do not produce interference (Styles, 1997). Further, in the present study, listening to music was not a salient task, but was a background element that participants may have chosen to attend to or not. Differences in attention level to the music would produce different levels of processing and would be expected to affect performance in different ways.

An alternative explanation, which may be more fruitful in describing the results of the present study, is the arousal research described by the Yerkes-Dodson Law (Boff & Lincoln, 1988). The Yerkes-Dodson Law, originally proposed in 1908, describes the relationship between performance and arousal as an inverted U-function. A minimal level of arousal allows for peak performance, such that insufficient or excessive arousal may lead to degraded performance. Further, the difficulty of the task and the environment contribute to

the arousal level (Boff & Lincoln). More difficult tasks generate greater arousal, as does greater environmental stimulation. During a low-level task, music increases arousal to an optimal level. For more difficult tasks, music increases the arousal beyond the optimal level, resulting in a degradation of performance (Beh & Hirst, 1999).

Investigation of the subjective difficulty ratings for the tasks utilized in the present and pilot studies are consistent with the theory of arousal proposed by the Yerkes-Dodson Law. The perceived difficulty level of the Memory Search Task when performed with music may not have been sufficiently high enough to produce the arousal necessary for optimal performance (Shingledecker, 1984). However, the perceived difficulty levels of the other tasks performed with music during the pilot and present studies may have been sufficiently high to generate increased performance.

Incidentally, reaction time was found to significantly increase with trial block during the linguistic task. Further, a significant interaction between trial block and difficulty level of the task was found, such that the reaction time decreased as trial block increased and difficulty level decreased during the linguistic task. Also, during the Spatial Processing Task, a significant main effect was found for trial block on reaction time, such that reaction time decreased as trial block increased. The effect of trial block was particularly surprising because they were based on previous research conducted on the Criterion Task Set.

Each trial block sequence followed the recommendation of Shingledecker (1984), who suggested that ten practice trials should be performed during the cognitive tasks to maximize performance stability. The introduction of music during the trial condition may explain the inconsistent trial block performance observed during the present study.

This study was not designed to test the reliability of the Mozart effect, as the Mozart effect has been refuted through multiple research efforts (e.g., Stough et al., 1994; Steele et al., 1999; Nantais & Schellenberg, 1999). However, the present study was conducted to provide a scientific basis to study the effects of music on cognitive task performance. Future study controlling for differences in linguistic and nonlinguistic processing, as well as controlling for vocal and nonvocal music will likely provide fruitful answers to whether or not music improves task performance, as well as when and under what conditions improvement might occur.

APPENDIX A

Informed Consent to Participate in a Psychology Research Study

Project Title:	Music and Cognitive Performance
Investigator(s):	Leslie Angel, <i>Investigator</i> (Dr. Don Polzella, <i>Faculty Supervisor</i>)
Description of Study:	You are being asked to participate in a research study that will determine if listening to background music will have any effect on your performance on a cognitive task. This requires that you participate in a standardized, computer-driven task while listening to previously selected music. If you have any questions or concerns at this time or throughout the study please do not hesitate to inform the experimenter.
Adverse Effects and Risks:	The participants will not experience any noxious or distasteful stimuli during their involvement in this study. Participants may experience slight fatigue during their involvement in the study, but will not be exposed to any lasting ill effects.
Duration of Study:	This study will take place in three one-hour sessions over the course of three days. As compensation for participating in this study, you will receive three experimental credits toward your PSY 101 course, one credit for each of the three one-hour sessions.
Confidentiality of Data:	All records of your participation will remain confidential and your name will not appear in any of the results. A participant number along with other participants' numbers will only be used to identify you and your responses in the data set.
Contact Person:	If you have any questions about this study, please contact Leslie Angel, at (937) 229-2175, 313 St. Joseph's Hall (SJ). You may also wish to contact Dr. Charles Kimble, chair of the Research Review and Ethics Committee, at (937) 229-2167, SJ 319.

Consent to Participate:

I have voluntarily decided to participate in this study. The investigator named above has adequately answered any and all questions I have about this study, the procedures involved, and my participation. I understand that the investigator named above will be available to answer any questions about research procedures throughout this study. I also understand that I may voluntarily terminate my participation in this study at any time and still receive full credit. However, I understand that in order to earn three research credit hours, I must be present for the second and third sessions of the study. I also understand that the investigator named above may terminate my participation in this study if s/he feels this to be in my best interest. In addition, I certify that I am 18 (eighteen) years of age or older.

Signature of Student
Date

Student's Name (printed)

Signature of Witness
Date

Research Credit Information:

PSY 101 Section _____ Instructor _____ Credits

Student ID# or Social Security Number _____

Credit for term _____

Researcher: Return this form to the Psychology Experiments Box in SJ 329

APPENDIX B

DEBRIEFING FORM

Information about the Study

Thank you for your participation in this study. This study was conducted to determine if listening to background music affects cognitive performance during a verbal or nonverbal task. Some participants performed a linguistic processing, or verbal task, while others participated in a spatial processing, or nonverbal task. While the effects of music on performance are not clear, differences in background music type has previously been shown to have no significant effect on performance (e.g., Freeburne & Fleischer, 1952; Salame & Baddeley, 1989). Mozart's music was selected as the background because it is rhythmic and melodic, and has previously been used in a number of studies. Consistency of the music selection also allows for greater control so that the effects of the music in general are detected rather than any variability within the music itself. Researching the effect of music on the participant's speed and accuracy during standardized tasks in this study can help determine the broader question of the benefits of incorporating music into academia, industry, and similar occupational settings to improve work performance.

References

- Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature*, 365, 611.
- Steele, K. M., Bass, K. E., & Crook, M. D. (1999). The mystery of the Mozart effect: Failure to replicate. *Psychological Science*, 10, 366-369.

Assurance of Privacy

We are researching general principles of cognition and are not evaluating you personally in any way. All records of your participation will remain confidential and your name will

not appear in any of the results. A subject code will only be used to identify you and your responses in the data set.

Contact Information

If you have questions about any aspect of this study, please contact Leslie Angel, at (937) 229-2175, 313 St. Joseph's Hall. You may also wish to contact Dr. Charles Kimble, chair of the Research Review and Ethics Committee, at (937) 229-2167, 319 St. Joseph's Hall.

Thank You and Credit

Thank you again for your participation in this study. Your research credit form will be handed in today so that you receive credit for your participation.

APPENDIX C

Effects of Music on Cognitive Task Performance – Mozart Selections

Klavierwerke (1)

Richard Fuller – Hammerflügel

1. Mozart K.545, Sonate C-Dur, 10:39
 Allegro, 3:11
 Andante, 5:29
 Rondo, 1:59
2. Mozart K.283, Sonate G-Dur, 18:49
 Allegro, 5:46
 Andante, 6:33
 Presto, 6:29
3. Mozart K.330, Sonate C-Dur, 17:34
 Allegro moderato, 6:11
 Andante cantabile, 5:34
 Allegretto, 5:47

Klavierwerke (2)

Richard Fuller – Fortepiano

5. Mozart K.570, Sonate B-Dur, Allegretto, 3:43
6. Mozart K.332, Sonate F-Dur, Allegro, 6:52
8. Mozart K.485, Rondo D-Dur, 6:09

Klavierwerke (3)

Richard Fuller - Fortepiano

10. Mozart K.331, Sonate A-Dur, Alla Turca: Allegretto, 3:38
12. Mozart K.333, Sonate B-Dur, Allegro, 7:35
13. Mozart K.333, Sonate B-Dur, Rondo: Allegretto grazioso, 6:46
15. Mozart K.311, Sonate D-Dur, Andante con espressione, 4:57

APPENDIX D

Linguistic Order 1

<i>Session 1</i>	<i>Session 2</i>	<i>Session 3</i>
<i>Linguistic Processing</i>	<i>Linguistic Processing</i>	<i>Linguistic Processing</i>
Low – Practice 1	Low – Practice 9	Medium/Music2 – Trial 17
Medium – Practice 2	Medium – Practice 10	Medium/No music – Trial 18
Low – Practice 3	<i>Linguistic Processing</i>	Low/Music2 – Trial 19
Medium – Practice 4	Low/Music2 – Trial 11	Low/No music – Trial 20
Low – Practice 5	Low/No music – Trial 12	Medium/Music2 – Trial 21
Medium – Practice 6	Medium/Music2 – Trial 13	Medium/No music – Trial 22
Low – Practice 7	Medium/No music–Trial 14	
Medium – Practice 8	Low/Music2 – Trial 15	
	Low/No music – Trial 16	

BIBLIOGRAPHY

- Acton, W. H., & Crabtree, M. S. (1985). *User's guide for the criterion task set.* (AAMRL-TR-85-034). Wright-Patterson Air Force Base, OH: Systems Research Laboratories, Inc.
- Beh, H. C., & Hirst, R. (1999). Performance on driving-related tasks during music. *Ergonomics*, 42, 1087-1098.
- Boff, K. R., & Lincoln, J. E. (1988). Arousal level: Effect on performance. *Engineering Data Compendium: Human Perception and Performance.* AAMRL. Wright Patterson Air Force Base, OH: Systems Research Laboratories, Inc.
- Chiles, W. D., Alluisi, E. A., and Adams, O. S. (1968). Work schedules and performance during confinement. *Human Factors*, 10, 143-196.
- Cockerton, T., Moore, S., & Norman, D. (1997). Cognitive test performance and background music. *Perceptual and Motor Skills*, 85, 1435-1438.
- Craik, F. I., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, 104, 268-294.
- Etaugh, C., & Ptasnik, P. (1982). Effects of studying to music and post-study relaxation on reading comprehension. *Perceptual and Motor Skills*, 55, 141-142.
- Flaum, M. P. (1981). The effects of music and noise upon verbal and visuospatial task performance among male college students. *Dissertation Abstracts International*, 42 (3B), 1169. (UMI No. 8111544).
- Fontaine, C. W., & Schwalm, N. D. (1979). Effects of familiarity of music on vigilant performance. *Perceptual and Motor Skills*, 49, 71-74.

- Freeburne, C. M., & Fleischer, M. S. (1952). The effect of music distraction upon reading rate and comprehension. *Journal of Educational Psychology, 43*, 101-109.
- Freeman, J., & Neidt, C. O. (1959). Effect of familiar background music upon film learning. *Journal of Educational Research, 53*, 91-96.
- Hahn, M., & Hwang, I. (1999). Effects of tempo and familiarity of background music on message processing in TV advertising: A resource-matching perspective. *Psychology and Marketing, 16*, 659-675.
- Hall, J. C. (1952). The effect of background music on the reading comprehension of 278 eighth and ninth grade students. *Journal of Educational Research, 45*, 451-458.
- Hilliard, O. M., & Tolin, P. (1979). Effect of familiarity with background music on performance of simple and difficult reading comprehension tasks. *Perceptual and Motor Skills, 49*, 713-714.
- Jensen, M. B. (1931). The influence of jazz and dirge music upon speed and accuracy of typing. *Journal of Educational Psychology, 22*, 458-462.
- Jex, H. R., McDonnell, J. D., & Phatak, A. V. (1966). Critical tracking task for manual control research. *IEEE Transactions on Human Factors Engineering, 7*, 138-145.
- Kerr, W. A. (1943a). Attitudes toward types of industrial music. *Journal of the Acoustical Society of America, 15*, 125-130.
- Kerr, W. A. (1943b). Where they like to work: Work place preferences of 228 electrical workers in terms of music. *Journal of Applied Psychology, 27*, 438-442.
- Kinnear, P. R., & Gray, C. D. (2000). Exploratory data analysis. *SPSS for Windows made simple*. (pp. 98-99). East Sussex: Psychology Press, Ltd.
- Mayfield, C., Moss, S. (1989). Effect of music tempo on task performance. *Psychological Reports, 65*, 1283-1290.
- Middleton, W. C., Fay, P. J., Kerr, W. A., Amft, F. (1944). The effect of music on feelings of restfulness-tiredness and pleasantness-unpleasantness. *Journal of Psychology, 17*, 299-318.

- Mikol, B., & Denny, M. R. (1955). The effect of music and rhythm on rotary pursuit performance. *Perceptual and Motor Skills*, 5, 3-6.
- Nantais, K. M., & Schellenberg, E. G. (1999). The Mozart effect: An artifact of preference. *Psychological Science*, 10, 370-373.
- Polzella, D. J., & Reid, G. B. (1987). A multidimensional scaling analysis of subjective workload assessment technique (SWAT) ratings of the criterion task set (CTS). *Proceedings of the Human Factors Society*, 31, 398-401.
- Pooch, G. K., & Wiener, E. L. (1966). Music and other auditory backgrounds during visual monitoring. *Journal of Industrial Engineering*, 17, 318-323.
- Posner, M. I., and Mitchell, R. F. (1967). Chronometric analysis of classification, *Psychological Review*, 74, 392-409.
- Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature*, 365, 611.
- Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1995). Listening to Mozart enhances spatial-temporal reasoning: Towards a neurophysiological basis. *Neuroscience Letters*, 185, 44-47.
- Schlegel, R. E., and Gilliland, K. (1987). *Evaluation of the criterion task set. (AFAMRL-TR-87-XXX)*. Wright-Patterson Air Force Base, OH: Air Force Aerospace Medical Research Laboratory.
- Shingledecker, C. A. (1984). *A task battery for applied human performance assessment research. (AFAMRL-TR-84-071)*. Wright-Patterson Air Force Base, OH: Air Force Aerospace Medical Research Laboratory.
- Schulman, A. I. (1974). Memory for words recently classified. *Memory and Cognition*, 2, 47-52.
- Smith, C. A., & Morris, L. W. (1977). Differential effects of stimulative and sedative music on anxiety, concentration, and performance. *Psychological Reports*, 41, 1047-1053.
- Smith, H. C. (1947). Music in relation to employee attitudes, piecework production, and industrial accidents. *International Review of Applied Psychology*, 14, 59.

- Smith, W. A. S. (1961). Effects of industrial music in a work situation requiring complex mental activity. *Psychological Reports*, 8, 159-162.
- Steele, K. M., Bass, K. E., & Crook, M. D. (1999). The mystery of the Mozart effect: Failure to replicate. *Psychological Science*, 10, 366-369.
- Sternberg, S. (1969). Memory scanning: Mental processes revealed by reaction time experiments. *American Scientist*, 57, 421-457.
- Stough, C., Kerin, B., Bates, T., & Mangan, G. (1994). Music and spatial IQ. *Personality and Individual Differences*, 17, 695.
- Styles, E. A. (1997). Task combination and divided attention. *The Psychology of Attention*. UK: Psychology Press Ltd.
- Wickens, C. D. (1991). Processing resources and attention. In D. L. Damos. *Multiple-Task Performance* (pp. 3-34). Washington, D.C.: Taylor and Francis.
- Wickens, C. D. (1984). Processing resources in attention. In R. Parasuraman & D. R. Davies, *Varieties of Attention* (pp. 63-102). Orlando: Academic Press, Inc.
- Winer, B. J. (1962). *Statistical Principles in Experimental Design*. New York: McGraw-Hill Book Company.
- Wolfe, D. E. (1983). Effects of music loudness on task performance and self-report of college-aged students. *Journal of Research in Music Education*, 31, 191-201.